Controlling Robots with a Spring in Their Step

Completed Technology Project (2015 - 2019)

Project Introduction

In future manned planetary exploration missions there is a strong logic that robots will remain central to the mission success. These robots may be called upon to construct habitats, maintain sensors, and assist astronauts both inside and outside the habitats. Yet these robots will have one especially stringent constraint which is not normally placed on legged systems: they must be safe. If legged space robots are to collaborate effectively alongside human partners in planetary missions, we will need controllers that can adapt to human-friendly mechanical designs. Robots with flexible joints appear to have the best potential for these human-oriented applications since this compliance allows them to react to unexpected collisions gently, rather than crushing unexpected disturbances with full motor power. However, joint flexibility achieves safety at the cost of responsiveness, slowing down the performance of the low-level torque control servo in each joint. Whole body controllers, which assume ideal, instantaneous torque sources, must therefore reduce their bandwidth--their speed and performance--to remain stable. Since this reduces the positional accuracy of the swing foot and center of mass while walking, compliant robots are prone to unsafe falls at even moderate speeds. Building on the safe interaction success of the Robonaut project, the Valkyrie Robot from JSC has safe, compliant actuators. My central aim is to demonstrate a new control strategy that supports stable, fast, responsive walking on compliant legs. I will develop a controller that explicitly compensates for non-ideal force sources. My hypothesis is that this controller will significantly improve walking performance and robustness, allowing Valkyrie to double her walking speed and allowing her to hold a glass of water as she does it. More specifically: (1) I will experimentally identify the collection of model parameters that most accurately predict the robot's behavior. This model will reflect linear dynamics between commanded and sensed torques as well as non-linear rigid body dynamics between sensed torques and robot motion. Then, (2) re-writing the whole body control framework, I will extend this controller to explicitly consider models with slow torque response and thus robots with flexible joints. (3) I will then apply some of the advanced control techniques I have learned in my graduate studies thus far to stabilize this more complex model. Specifically, between the infinite choices of stabilizing controllers, I will chose one which produces a closed loop compliant system with good center of mass and pitch position tracking and compliant swing foot searching. Finally, (4) I will test the validate and tune the performance of this controller by testing on the physical robot. This research could transform the related field of compliant walking robot design from an art to a science, providing a way to estimate the limits of robot performance in advance of construction. And it could potentially lead to improvements in high speed mobile manipulation and collaborative manipulation between compliant joint legged robots and astronauts. This work also has the potential for global societal scope beyond space technology. Equipped with a robust walking controller, compliant humanoid robots will be safe to have around the house. With improved walking, NASA astronauts, factory workers, and consumers

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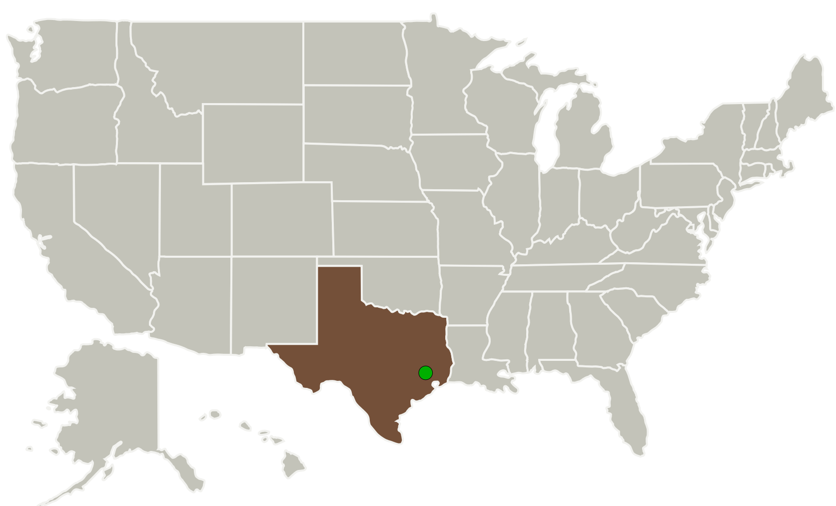
alike will be able to rely on these robots to maintain balance given realistic disturbances, and robots will then be able to fill service areas that require locomotion in close proximity to people: caring for the elderly, delivering goods door-to-door, moving furniture, and tending to people with communicable infections. Robots capable of responsive, flexible and safe interactions with their environments and the people in their environment will create many scientific and engineering opportunities.

Anticipated Benefits

This research could transform the related field of compliant walking robot design from an art to a science, providing a way to estimate the limits of robot performance in advance of construction. And it could potentially lead to improvements in high speed mobile manipulation and collaborative manipulation between compliant joint legged robots and astronauts. This work also has the potential for global societal scope beyond space technology. Equipped with a robust walking controller, compliant humanoid robots will be safe to have around the house. With improved walking, NASA astronauts, factory workers, and consumers alike will be able to rely on these robots to maintain balance given realistic disturbances, and robots will then be able to fill service areas that require locomotion in close proximity to people: caring for the elderly, delivering goods door-to-door, moving furniture, and tending to people with communicable infections. Robots capable of responsive, flexible and safe interactions with their environments and the people in their environment will create many scientific and engineering opportunities.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

The University of Texas at Austin

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Luis Sentis

Co-Investigator:

Gray C Thomas

Organizations Performing Work	Role	Type	Location
The University of Texas at Austin	Lead Organization	Academia	Austin, Texas
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

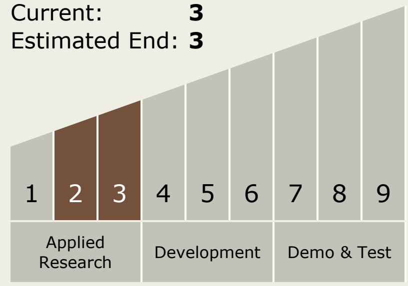
Primary U.S. Work Locations
Texas

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX10 Autonomous Systems
  └ TX10.2 Reasoning and Acting
    └ TX10.2.4 Execution and Control

Target Destinations

Earth, The Moon